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AGARD Corrosion Handbook Volume 2 Aircraft Corrosion Control Documents: A Descriptive Catalogue

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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

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AGARDograph No.278

AGARD CORROSION HANDBOOK

VOLUME 2

AIRCRAFT CORROSION CONTROL DOCUMENTS:

A DESCRIPTIVE CATALOGUE

by

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This AGARDograph was prepared on behalf of the Corrosion Subcommittee of the Structures and Materials Panel of AGARD.

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— Exchanging of scientific and technical information;

— Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

— Improving the co-operation among member nations in aerospace research and development;

— Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);

— Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;

— Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

— Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

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PREFACE

This is the second part of a Handbook of Aircraft Corrosion produced by the Structures and Materials Panel. The first part covers the theory of, and some experiences with, metallic corrosion as related to the observed behaviour of real aircraft structures.

This volume catalogues sources of information and requirements for corrosion control obtained from documents issued by NATO, France, UK and US authorities. IATA (International Air Transport Association) documents are also cited as a commercial reference.

* * *

RESUME

Ce volume, produit par le Panel des Structures et Matériaux de l'AGARD, constitue la seconde partie d'un Manuel sur la Corrosion des Aéronefs. Les sources d'information et de spécification du contrôle de la corrosion obtenues à partir des documents issus de l'OTAN et des autorités des pays comme la France, le Royaume-Uni et les Etats-Unis, sont cataloguées dans ce volume. Des documents de l'AITA (Association Internationale des Transports Aériens) sont également cités comme référence d'origine commerciale.

CONTENTS

INTRODUCTION

It is the intent of this handbook to provide a ready source of information on the problems of corrosion prevention and control of NATO aircraft. The information is arranged in an easily accessible tabular form and is extracted from pertinent NATO, U.S., U.K., and French documents. The International Air Transport Association (IATA) is also cited as a commercial reference.

As an example, if one requires information on stress corrosion cracking of aircraft steels, it is available in sections I.B. "Selection of Steels" and II.A. "Stress Corrosion Cracking and Hydrogen Embrittlement Corrosion Mechanisms". These paragraphs provide brief information on stress corrosion cracking. They would also direct you to specific sections of the applicable reference documents for more detailed information.

The aircraft corrosion control documents used by different countries are all very similar. Differences are principally in emphasis and approach. Each country recognizes that corrosion control is most easily accomplished at the design stage and each provides guidelines or mandatory requirements for the designer. Many of the documents emphasize corrosion control from the manufacturing stage through the service life of the aircraft. There are also suitable descriptions of the theoretical background and importance of corrosion control. NATO, MILITARY REQUIREMENTS, STEELS, MAGNESIUM, TITANIUM, STRESS CORROSION, GALVANIC CORROSION, DRAINAGE, ALUMINUM ALLOYS, CATALOGUE

Each service (Army, Navy and Air Force) in the United States employs different documents for controlling materials and processes during aircraft design and fabrication. The U.S. Navy uses General Specification SD-24; the Army uses Aeronautical Design Standard ADS-13 and DARCOM-R-702-24. The Air Force uses Military Standard MIL-STD-1568. All are generally in good agreement. For example, all prohibit or restrict the use of magnesium alloys, all require faying surface sealing, and all require "wet" installations of fasteners with sealant or primer. Differences are principally in the degree of protection required. With each revision of the documents, there appears to be closer and closer agreement among the services.

The United Kingdom and France do not employ different standards for each service. Instead, one controlling standard is used by all the services. In the United Kingdom, it is U.K. Ministry of Defence Standard DEF STAN 00-970. In France, Regulation AIR 7251 is used.

Many very detailed "leaflets" form a part of DEF STAN 00-970. Each "leaflet" covers a specific topic or material description that is pertinent to aircraft corrosion control (treatment of aluminum alloys, exfoliation of aluminum alloys, stress corrosion cracking, etc.). Background information on theory, the selection of alloys, and techniques for minimizing corrosion are given together with special precautions required for each material. The "leaflets" are written with a view to optimization of the design with respect to corrosion resistance.

The French standard, AIR 7251, contains very detailed information on assembly procedures and the preparation of a corrosion control plan. The remaining sections are more general with a limited number of specific references given. The rules for equipment protection are very stringent, but there is a provision for "lightened protection" in accessible areas that are not in a very corrosive environment. Permission to apply "lightened protection" must be obtained from the STA (Service Technique de l'Aéronautique).

In addition to the specification and standards for material and processes employed in the design and manufacturing stages of aircraft, there are many sub-tier specifications. Specification MIL-F-7179 is used by all the U.S. services for finishing aircraft. MIL-S-5002 covers inorganic coatings (electroplating, etc.). MIL-STD-889 gives detailed information on dissimilar metals and methods of minimizing galvanic corrosion. There is also a special publication, NAVMAT P4855-2, that provides design guidelines for the prevention and control of avionic corrosion.

Two documents are referenced which have impact on more than one country. They are International Air Transport Association Document IATA DOC. GEN/2637A entitled "Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures" and Agard Corrosion Handbook Volume I entitled "Aircraft Corrosion: Causes and Case Histories."

IATA DOC. GEN/2637A addresses corrosion preventive design of commercial aircraft and is heavily based in previous lessons learned with a great deal of common sense subjects addressed in addition to the normal materials and processes found in the military documents.

Finally, the AGARD Corrosion Handbook, Volume I is a good source of metallurgy and corrosion theory. In addition to the materials and processes which are addressed in clear, simple, and brief explanations, a large number of examples of different in-service corrosion related failures and investigations are provided. This source is a suitable general reference and contains excerpts from all of the other NATO corrosion documents.

The following volume is presented in a tabular fashion with narrative remarks providing a preface to each table with an overview of the general approach to a topic and highlight any exceptions to generally accepted corrosion preventive practices.

A

I. Selection of Materials

A. Aluminum Alloys

The design manuals used by the NATO countries contain considerable information to highlight corrosion problems encountered with aluminum alloys and aid in the selection of aluminum alloys.

The general metallurgy of aluminum alloys as well as descriptions of the various corrosion mechanisms and the effects of processing variables and alloying elements on corrosion susceptibility are contained in the AGARD Corrosion Handbook, Volume I. Case histories of corrosion failures in aluminum alloy aircraft parts also are given.

Both Volume I (fixed wing aircraft) and Volume 2 (rotary wing aircraft) of SD-24 contain design requirements for aluminum alloys to be used in U.S. Navy aircraft. These include minimum gage, selection of intergranular and stress corrosion resistant alloys, recommended alloys, and prohibitions against practices such as fusion welding of clad high strength alloys.

Specific design guidelines for the selection of aluminum alloys for U.S. Army aircraft are given in Aeronautical Design Standard ADS-13. The section on alloy selection is similar to that in SD-24. There is a table of resistance of stress corrosion cracking of 2000 and 7000 series alloys. ADS-13 is more specific than SD-24 in some of its prohibitions. Alloys known to have a history of corrosion problems (2020, 7079, and 7178) are prohibited. The use of 7000 series alloys in the T-6 temper condition is limited to thickness not to exceed 0.188 inch (4.78 mm). Both SD-24 and ADS-13 give requirements on maximum metal removal from the surfaces of parts, and shot peening of parts.

The U.S. Air Force document for materials and processes for corrosion control, MIL-STD-1568, is exactly the same as the Army's ADS-13 with respect to aluminum alloys. It includes the same table of SCC resistance, the same selection limitations, shot peening requirements and stress corrosion factors. The instruction used by France, AIR 7251, presents general information on the behavior of aluminum alloys and specific information on the behavior of some aircraft alloys (alloy designations are in French only). The United Kingdom provides very concise, but fairly complete information to the designer by way of "Leaflets" that make up Defence Standard 00-970. There is a specific leaflet on exfoliation corrosion of aluminum alloys and precautions to be taken to avoid it. The effects of alloying elements and heat treatments are given. A table of relative susceptibilities of United Kingdom and American alloys is included. Another "Leaflet" covers the whole subject of stress corrosion cracking. The stress corrosion cracking of aluminum alloys is explained in this leaflet and a table of relative susceptibilities of aluminum alloys to SCC is given. Other leaflets contain special requirements according to the basic subject discussed.

The International Air Transport Association's guidance material on design and maintenance against corrosion of aircraft structures is more or less general with respect to aluminum. However, 2020 and 7079 aluminum alloys are considered unsatisfactory and it is recommended that the use of 7075-T6 plate be prohibited for structural applications, except in controlled situations. It is also required that exterior surfaces of the fuselage be made of clad aluminum.

DESIGN DOCUMENT (COUNTRY)	I. Selection of Materials A. Aluminum Alloys
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.2.1.1 provides a table of minimum gages. Par. 3.2.2.1.2 provides a list of exfoliation resistant alloys in addition to a list of stress corrosion resistant alloys. It also prohibits fusion welding of clad alloys and the use of perforated core materials.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Selection of aluminum alloys is not addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Selection of aluminum alloys is not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.1.1 addresses alloy selection. Table 3 provides stress corrosion resistance ratings for several alloys and tempers in the short transverse direction. In addition, all aluminum sheets used in external environments are required to be clad. Par.3.3.3.1.2 addresses aluminum alloy selection and prohibits mill product forms 2020, 7079, and 7179 alloys.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Selection of aluminum alloys is not addressed.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Selection of aluminum alloys is not addressed.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 3,211 provides a general description of corrosion behavior. Par. 3,212 provides a description of the corrosion behavior of specific French alloys A-G3, A-G5, A-U4G1, A-U4G, A-U4SG, A-Z5GU, and A-U2GN.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Chap 405 prohibits the use of aluminum alloys with low exfoliation resistance (Category D)and restricts the use of aluminum alloys with moderate exfoliation resistance (Category C). Leaflet 405/1 provides a general explanation of exfoliation corrosion. Table I has the relative exfoliation corrosion ratings for several wrought alloys in U.S. and U.K. designations. Chap 6 addresses SCC.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Par. 3.3.3 (i) prohibits use of 2020 and 7079 alloys. Par. 3.3.4(i) recommends prohibition of the use of 7075-T6 plate in structural application except in Material on Design and "controlled" situations. Par. 3.3.5 requires exterior surfaces of the fuselage to be made from clad aluminum or anodized aluminum if this is not possible.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.1.1 addresses alloy selection and is nearly a duplicate of Par. 3.3.3.1.1 of ADS-13G. The identical table of relative SCC resistance is also provided. All comments for Par. 3.3.3.1.1 of ADS-13C above repeated. Par. 5.4.3.1.1. addresses aluminum alloy selection limitations. Mill product forms of alloys 2020, 7079, and 7178 in all temper conditions is prohibited.
MIL-STD-889. Dissimilar Metals. (U.S.)	Table I is a guide to use of joined structural metals and alloys and protective systems for service in sea water, marine atmosphere and industrial atmosphere. Table II provides a galvanic series of selected metals (including aluminum) in sea water. Appendix A Par. 30.4 addresses treatments for aluminum and aluminum alloys in descending order of preference.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Table 4-3 provides typical room temperature properties of some common aerospace aluminum alloys. Fig. 4-4 provides data on the effect of quenching rate on corrosion resistance of nonclad, wrought aluminum alloy specimens. In general this source is excellent for providing the metallurgy and corrosion theory necessary to better understand corrosion in each alloy, form, and condition.

I. Selection of Materials

B Steels

The AGARD Corrosion Handbook, Volume 1 gives the general corrosion properties of carbon and low alloy steels, and their resistance in various environments. Much emphasis is placed on ultra high strength steels (yield strength 1400 MPa and above) and examples of service failures by various mechanisms are given. There are explanations of hydrogen embrittlement, stress corrosion cracking, uniform corrosion, pitting, corrosion fatigue, and crevice corrosion. SD-24 contains the requirements for the selection of steels to be used in U.S. Navy aircraft including minimum gages, permissible variations in strength level, and restrictions on the processing of steels.

Except for general requirements such as using the lowest strength level practical, there is little information in ADS-13 or DARCOM-R 702-24 on the selection of steels. High strength steels are defined as steels of 1242 MPa and above ultimate tensile strength.

The selection of steels is not addressed in NAVMAT P4855-2 and only covered very generally in the U.S. Air Force MIL-STD 1568 and the French AIR 7251. United Kingdom Ministry of Defence DEF STAN 00-970, Volume, 1, Leaflet 406/1 covers the stress corrosion and hydrogen embrittlement of steels. The influence of heat treatment on SCC of steels is included. There is also a table of relative susceptibilities of some steels to SCC. (The table lists only United Kingdom designations.)

The International Air Transport Association's DOC. GEN/2637 does not provide specific information on the selection of non-corrosion resistant steels other than recommending that the use of maraging steel bolts be prohibited. However, it does provide a very good overview of the corrosion problems and indicates the corrosion prone areas in aircraft.

DESIGN DOCUMENT (COUNTRY)	I. Selection of Materials B. Steels
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.2.1.1 provides minimum gages required in using steels. Par. 3.2.2.1.2.1 gives tensile strength limits, preferred compositions, precautions and prohibitions with respect to using steels.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Selection of steels is not addressed.
MIL-F-7179F. Finishes,Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Selection of steels is not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.1.2. addresses low alloy, high strength steel.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Selection of steels is not addressed.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Selection of steels is not addressed.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes et Autres Materials Aeronautiques. (France)	Par. 3,231 gives general information on the corrosion behavior of steels.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Leaflet 406/1 section 4 covers steels, including general information on susceptibility to SCC and hydrogen embrittlement. Heat treatment and stress relieving are also covered. Table 3 gives relative susceptibilities to SCC of various steels but only as U.K. alloy designations.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Par. 3.3.4 (ii) prohibits use of maraging steel bolts except in "controlled" environments.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.2.2 provides design guidelines, precautions, and procedures to be followed to minimize stress corrosion factors in alloy steel parts.
MIL-STD-889. Dissimilar Metals. (U.S.)	Table I is a guide to use of joined structural metals and alloys and protective systems for service in sea water, marine atmosphere and industrial atmosphere. Table II is a galvanic series of selected metals (including steel) in seawater. Appendix A Par. 30.5 addresses treatments for carbon and low alloy steels in descending order of preference.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Chap. 4.2 provides a general overview of the metallurgy and corrosion theory involved in proper selection of aircraft steels to maximize corrosion resistance.

I. Selection of Materials

C. Magnesium Alloys

Because of severe corrosion problems encountered with magnesium alloys in the past, the use of magnesium alloys is either prohibited or limited in all current design guidelines. SD-24 (U.S. Navy) prohibits the use of magnesium alloys "unless otherwise specified in the detail specification". ADS-13 (U.S. Army) requires approval of the U.S. Army Aviation Research and Development Command (AVRADCOM) before any application of magnesium alloys. Use of magnesium is prohibited in erosion and wear applications and in parts not readily accessible for inspection. Parts are required to be anodized.

AIR 7251 (Ministry of Defense, France) requires magnesium alloy raw materials to be chromate coated, preservative coated, or primed during storage. Magnesium may not be used for parts in inaccessible areas, strict conformance with finishing requirements is required, and magnesium parts must be named in the protection plan.

The U.S. Navy's design guidelines for corrosion control of avionics equipment recommends that the use of magnesium alloys be avoided if possible.

United Kingdom's Defence Standard 00-970 has a "Leaflet" devoted entirely to precautions to be taken in the use of magnesium parts. Magnesium alloy skins or parts made from magnesium alloy sheet are prohibited for military aircraft. Magnesium alloys may be acceptable in certain applications provided all the precautions given in the "Leaflet" are observed. A list of places where magnesium parts should not be used is given.

DOC. GEN/2637 of the International Air Transport Association recommends that magnesium alloys be prohibited from structural applications.

Volume 1 of the AGARD Corrosion Handbook contains considerable information on the metallurgy and corrosion behavior of magnesium alloys. Case histories of magnesium part failures also are included.

DESIGN DOCUMENT (COUNTRY)	I. Selection of Materials C. Magnesium
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.2.1.4 prohibits the use of magnesium alloys unless otherwise specified in the detail specification.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Selection of magnesium alloys is not addressed.
MIL-F-7179F. Finishes,Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Selection of magnesium alloys is not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 4.2.8 requires approval of AVRADCOM prior to using magnesium, prohibits use of magnesium in erosion and wear applications, requires readily accessible inspection provisions, and requires anodized finish plus organic coating on all parts. Appendix I Par. 3.3.3.1.8 provides a detailed explanation of permissible areas of use.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Appendix A Par. 1.8.1 requires justification for the use of magnesium. A long duration protective system is required, with regular inspection without extensive disassembling of structures.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 4.2 provides a detailed treatment procedure for magnesium used in avionic components. Section 5.2 discourages the use of magnesium in avionics equipment.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes et Autres Materials Aeronautiques. (France).	Section 2 requires protective finish for magnesium alloy in storage. Par. 3,22 contains a general description of the corrosion behavior of magnesium. Par. 3,333 contains a general discussion of coating requirements prior to force fitting magnesium parts. Par. 4,33 contains explanations of protective methods for magnesium. Par. 5,22 provides surface preparation requirements prior to painting.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Leaflet 400/2 covers precautions to be taken in the use of magnesium, but states that skins or parts made from magnesium sheet should not be used in military aeroplane structures. Many applications in which magnesium should not be used are given.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Par. 3.3.3 (iii) states that magnesium alloys should be prohibited from structural applications.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.5 requires that specific approval be obtained from the procuring activity in the event magnesium must be used. Specific limitations of use for applications which are approved are provided.
MIL-STD-889. Dissimilar Metals. (U.S.)	Table I is a guide to use of joined structural metals and alloys and protective systems for service in sea water, marine atmosphere and industrial atmosphere. Table II is a galvanic series of selected metals (including magnesium) in seawater. Appendix A Par. 30.1 provides treatments for magnesium in descending order of preference.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Chap. 4.4 gives general information of a corrosion and metallurgical background about magnesium. Table 4-4 explains the standard four part ASTM system of magnesium alloy and temper designations. Section 4.4.1 covers cast magnesium alloys. Section 4.4.2 covers wrought, heat treatable magnesium alloys.

I. Selection of Materials

D. Titanium

The metallurgy and general corrosion behavior of titanium is succinctly discussed in the AGARD Corrosion Handbook, Volume 1. Titanium is strongly resistant to corrosion as long as a protective film of TiO_2 is permitted to form on the surface. The most protective TiO_2 films form in the presence of low levels of water in the atmosphere. Titanium is susceptible to corrosion in environments which destroy the protective oxide film either chemically or mechanically (i.e. fretting).

The U.S. Navy's general design specification, SD-24 gives requirements for minimum thicknesses for titanium and titanium alloys. The U.S. Army's ADS-13 provides limitations similar to those in SD-24 with regard to surface consideration to prevent stress concentrations which could permit stress corrosion or hydrogen embrittlement. Additionally, ADS-13 provides warning about fretting of titanium as well as warning of contact with cadmium, silver brazing, or particular chemicals. The U.S. Air Force's MIL-STD-1568 contains the same information and limitations as ADS-13 presented in nearly identical words. MIL-STD-889 provides tables of galvanic compatibility in seawater, marine, and industrial atmospheres. Treatments for titanium are provide in Appendix A in descending order of preference based on the application of the titanium part. This information is unique to MIL-STD-889. Finally, NAVMAT P4855-2 addresses the use of titanium very briefly in a galvanic chart which relates titanium to other materials.

France's AIR 7251 has no information on the selection of titanium. It is devoted largely to the protection of aircraft parts and assemblies. United Kingdom's Defence Standard 00-970 gives general requirements for avoiding penetration of titanium alloys by cadmium. In addition, Defence Standard 00-970 gives general requirements for avoiding stress corrosion. General guidance is provided in Chapter 801 for surface treatment of titanium alloys in contact with other materials. The United Kingdom indicates particular caution for contact of fluorinated polymers and phosphate ester hydraulic fluid in contact with titanium.

The IATA provides titanium related information in the appendices of IATA Document Gen/2673A, Issue 2. Appendix 1 provides examples of corrosion due to improper use of titanium in aircraft manufacture. Appendis 2 provides cautions and prohibitions for general use of titanium during the design phase of aircraft.

Documents which do not address selection of titanium are MIL-S-5002, MIL-F-7179, and DARCOM-R-702-24.

DESIGN DOCUMENT (COUNTRY)	I. Selection of Materials D. Titanium
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.2.1.1 gives minimum gages of titanium alloy parts and hydraulic tubing.
MIL-S-5002C.Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems. (U.S.)	Selection of titanium alloys is not addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Selection of titanium alloys is not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.1.7.1 provides minimum surface requirements. Par. 3.3.3.1.7.2 provides strong warning to prevent fretting in structural applications. Par. 3.3.3.1.7.3 forbids the use of cadmium plating or allowing titanium to come in contact with cadmium. Par. 3.3.3.6.3 permits dry installation of titanium, monel, or stainless steel fasteners in titanium structures.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Selection of titanium alloys is not addressed.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Table 2-2 provides an excellent chart for relating the galvanic character of titanium to other materials.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion des Aerodynes Et Autres Materials Aeronautiques	Par. 3,24 requires no coating to protect titanium but a coating is suggested when titanium contacts other materials. Titanium causes galvanic couple and fretting problems. The galvanic character of titanium is compared in annexe 2 (Appendix 2) with that of other metals.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Chap. 801 Par. 13 provides guidance on surface treatment of titanium alloys in contact with other materials. Particular caution is indicated for contact with fluorinated organic polymers and phosphate ester hydraulic fluids. Leaflets 801/1 and 801/2 precaution against corrosion and deterioration. Leaflet 406/1 Par. 5 addresses titanium stress corrosion cracking susceptibility in titanium.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Appendix 1 Par. 3 provides several examples of galvanic corrosion due to contact with titanium parts. Appendix 2 Par. 1.3.4 requires no finish over titanium with the exception of titanium in contact with aluminum. It also prohibits cadmium plating over titanium and titanium use in high temperature areas (i.e. >120°C) with possible liquid spillage such as phosphate ester fluids.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.4.1 requires all titanium mill products to be 100% machined, chemically milled, or pickled to remove all contaminated zones and layers formed at elevated temperatures. Par. 5.4.3.42 precautions dealing with titanium fretting. Par. 5.4.3.4.3 and 5.5.1.1 caution about cadmium/silver contact and chemical contamination. Par. 5.9.3 addresses titanium fastener sealing.
MIL-STD-889. Dissimilar Metals. (U.S.)	Table I is a guide to use of joined structural metals and alloys and protective systems for service in sea water, marine atmosphere and industrial atmosphere. Table II is a galvanic series of selected metals (including titanium) in seawater. Appendix A Par. 30.10 provides treatments for titanium in descending order of preference.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Chap. 4.5 gives general information of a corrosion and metallurgical background about titanium. Table 4-5 is a comparison of galvanic cell potentials with transpassive potentials and a comparison of galvanic corrosion currents with sweep corrosion currents. Table 4-6 provides typical room temperature properties of some common aerospace titanium alloys.

I. Selection of Materials

E. Corrosion Resistant Steels

Austenitic and martensitic stainless steels, age hardening steels (precipitation hardening), and nickel chromium steels are classified as corrosion resistant steels in this manual. The metallurgy and general corrosion behavior of these steels is discussed in AGARD Corrosion Handbook, Volume 1. The U.S. Navy's general design specification, SD-24, gives requirements for minimum thicknesses of corrosion resistant steels and limitations to be observed in their selection and use. In addition to several other prohibitions, the use of 431 or 19-9 DL steel is prohibited, precipitation hardening (PH) steels are required to be aged at not less than 1000°F, and fusion welding of unstabilized austenitic stainless steels is prohibited.

The U.S. Army's ADS-13 contains limitations very similar to those in SD-24. Corrosion resistant 19-9 DL and 431 steels are prohibited for use in any application, and maraging, Almar series, and custom series steels are not to be used in sustained load applications. Several more limitations are listed and there is also a table of general corrosion resistance and stress corrosion resistance of the most common corrosion resistant steels. The U.S. Air Force's MIL-STD-1568 contains the same limitations and the same table as ADS-13.

France's AIR 7251 has no information on the selection of corrosion resistant steels. It is devoted largely to the protection of aircraft parts and assemblies. United Kingdom's Defence Standard 00-970 gives general requirements for avoiding stress corrosion prone materials and requires approval of the Aeroplane Project Director before any material categorized as susceptible to stress corrosion cracking can be used. One of the "Leaflets" in Defence Standard 00-970 is devoted to the subject of stress corrosion cracking. Background information on corrosion resistant steels is included in the leaflet, and a table of relative susceptibilities to SCC of various alloys is given. (The table contains only English alloy designations.)

The only material in International Air Transport Association DOC.GEN/2637 concerned specifically with the selection of corrosion resistant steels is a recommendation for prohibiting the use of maraging steel bolts in uncontrolled structural applications. ("Controlled" applications are defined.) The remainder of the document covers finishing, assembly, and design considerations other than material selection.

DESIGN DOCUMENT (COUNTRY)	I. Selection of Materials E. Corrosion Resistant Steels
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.2.1 addresses minimum gages. (Table) Par. 3.2.2.1.2.2 gives limitations on use of corrosion resisting steels, prohibits fusion welding of austenitic steels or use in 750-900°F range. It also prohibits use of A31 or 19-9 DL steels, requests aging of PH steels at 1000°F or higher and maraging steels at 900°F, and prohibits use of 400 series steels in the 150,000 to 180,000 psi range.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems. (U.S.)	Selection of corrosion resistant steels is not addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Selection of corrosion resistant steels is not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.1.6 gives limitations very similar to those listed above for SD-24L. Table 4 lists resistance to general corrosion and SCC for various alloys.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Appendix A, Par. 1.8.6 provides general precautions to follow to prevent intergranular corrosion and SCC. Stainless steels are among the materials discussed.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Selection of corrosion resistant steels is not addressed.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France).	Par. 3,232 addresses the normal protection required for stainless steel parts.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Leaflet 806/6 provides precautions against corrosion and deterioration. Selection and use of corrosion resistant steels are addressed. Material characteristics, selection criteria, design considerations, manufacturing considerations, and protection methods are provided.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Appendix 2, Par. 1.3.1 provides minimum treatment requirements. Par. 2.3.2.2 provides cautions to be followed before and after resistance welding.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.3 requires passivation of all corrosion resistant steels and coating of 400 series steels. Par. 5.4.3.3.1 prohibits use of PH steels in H900 condition, use of maraging corrosion resistant steels in sustained load applications, use of 19-9 DL or 431 steels in any application, and use of 400 series martensitic steels in the 150,000 to 180,000 psi range.
MIL-STD-889. Dissimilar Metals. (U.S.)	Table I presents information on the compatibility of corrosion resisting steels with other metals.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Par. 4.2.3 provides information on the metallurgy, properties, and corrosion resistance of austenitic stainless steels. Par. 4.2.4 covers martensitic stainless steels. Par. 4.2.5 covers age hardening steels such as PH types. Par. 4.2.6 covers nickel chromium steels.

I. Selection of Materials

F. Other Metals

"Other metals" are all metals other than aluminum alloys, steels, magnesium alloys, titanium alloys, and corrosion resistant steels. There is very little material in the design guides to aid the designer in the selection of other metals, probably because there are comparatively few parts made of these materials. They also have good corrosion resistance for the most part.

The U.S. Navy's SD-24 does have some requirements for beryllium alloys, copper alloys, and nickel base alloys. Beryllium and beryllium base alloys are prohibited for use in aircraft "unless otherwise specified in the detail specification." Recommendations are given for specific bronze bearing alloys in various applications, and for nickel and cobalt base "superalloys" in welded ducting and in castings.

The U.S. Army's ADS-13 and U.S. Air Force's MIL-STD-1568 provide precautions to be followed where beryllium is an approved material, restrict the use of mercury and mercury containing compounds, and give finishing requirements for depleted uranium.

The AGARD Corrosion Handbook, Volume l, has a table listing the appearance of corrosion products of copper base alloys, nickel base alloys, cadmium, and chromium.

Most of the design guides have sections on galvanic corrosion, for which "other metals" require special treatment. Several also give specific requirements for finishing "other metals." Both of these subjects are addressed in other sections of this manual.

DESIGN DOCUMENT (COUNTRY)	I. Selection of Materials F. Other Metals
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.2.1.6 covers a few requirements for the selection of copper base Specific beryllium copper and bronze alloys are recommended for high and moderate bearing loads, respectively. Acceptable nickel and cobalt base superalloys for welded ducting and castings are listed.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems. (U.S.)	Selection of other metals is not addressed.
MIL-F-7179F. Finishes,Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Selection of other metals is not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.1.9 provides precautions to be followed in applications where beryllium is an approved material. Par. 3.3.3.1.10 restricts the use of mercury or mercury containing compounds in contact with aluminum and titanium alloys.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Selection of other metals is not addressed.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Selection of other metals is not addressed.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 3.3.1.4.5 addresses metal-wood assemblies and prohibits direct wood-magnesium assemblies. Appendix 1 Par. 4.3 addresses the protection of copper alloy assemblies per the corrosion protection plan.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Selection of other metals is not addressed.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Selection of other metals is not addressed.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.6 recommends suitable tested protective coating system for applications where beryllium is an approved material. Par. 5.4.3.7 prohibits the use of devices containing mercury on installed equipment or during production where spillage can contact aluminum and titanium causing accelerated stress cracking.
MIL-STD-889. Dissimilar Metals. (U.S.)	Table II provides a "galvanic series of selected metals in seawater."
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Table 5-1 which addresses the nature and appearance of corrosion products of various metals lists copper base alloys, cadmium, and chromium corrosion products and corrosion mechanism susceptibility.

II. Corrosion Mechanisms

A. Stress Corrosion Cracking and Hydrogen Embrittlement

All the design documents used by the AGARD countries contain information on the susceptibility of various metals and alloys to stress corrosion cracking as well as treatments and protective systems for minimizing stress corrosion. SD-24, Volume 1 (U.S. Navy), provides a table of stress corrosion resistant aluminum alloys and a general discussion of factors to be considered in preventing stress corrosion cracking and hydrogen embrittlement. ADS-13 (U.S. Army) gives tables of relative resistance to stress corrosion cracking for most of the currently employed aluminum alloys and corrosion resistant steels. ADS-13 also provides general information on methods for minimizing stress corrosion cracking. NAVMAT P4855-2 (U.S. Navy) contains a short description. Regulation AIR 7251 (France) defines stress corrosion, gives information on aircraft alloys sensitive to stress corrosion, and points out the risk of stress corrosion in force fit parts. Defence Standard 00-970, Volume 1, Leaflet 406/1 (U.K.), is devoted entirely to stress corrosion cracking. It is very complete in its presentation of the factors influencing stress corrosion cracking, especially in aluminum alloys, steels, and titanium alloys. IATA Document Gen/2637A, Issue 2, recommends avoidance of designs that produce residual tensile stresses in the short transverse grain flow direction. MIL-STD-1568 (U.S. Air Force) gives tables listing the susceptibilities to stress corrosion of aluminum alloys and corrosion resistant steels. Materials with known histories of stress corrosion cracking problems are given and are prohibited for use in aircraft. General stress corrosion factors such as press fits and sustained tensile stresses are discussed, and specific contaminants that cause stress corrosion cracking in titanium alloys are listed. The most complete discussion of stress corrosion cracking mechanisms, and the effects of heat treatment, alloying elements, and environmental conditions is given in Volume 1 of the AGARD Corrosion Handbook. Several case histories of stress corrosion cracking failures in aircraft parts are also given.

DESIGN DOCUMENT (COUNTRY)	II. Corrosion Mechanisms A. Stress Corrosion Cracking and Hydrogen Embrittlement
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.4.1.2.1 provides information on stress corrosion and hydrogen embrittlement.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems. (U.S.)	Par. 3.7.3.1.5 addresses coating systems which will avoid stress corrosion and hydrogen embrittlement in steels treated a tensile strength level of 240,000 psi or above. Par. 3.7.3.1.6 permits coating steel parts heat treated 240,000 psi with electroplating or as specified in Par. 3.7.3.1.5
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Stress corrosion cracking and hydrogen embrittlement are not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.1.1.1 addresses aluminum alloys and provides SCC topics of concern. Table 3 provides a rating of relative SCC resistance for the short transverse test direction for rolled plate, rod and bar, extrusions, and forgings. Par. 3.3.3.1.2 and 3.3.3.1.4 address SCC and steel. Par. 3.3.3.1.5 and 3.3.3.1.6 address SCC and corrosiion resistant steel.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Appendix A Section 1.8.6 addresses stress corrosion. Appendix A Section 1.8.7 addresses hydrogen embrittlement.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 4 addresses common corrosion problems. Par. d addresses stress corrosion.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 3,211 defines stress corrosion in aluminum alloys. Par. 3,212 defines french aluminum alloy designations which have a pronounced sensitivity to stress corrosion. Par. 3,231 addresses stress corrosion and hydrogen embrittlement in high strength steels. Section 3,33 address force fits and SCC in aluminum, steel and magnesium.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Chapter 406 addresses stress corrosion cracking. Leaflet 406/1 address stress corrosion cracking in greater detail for aluminum alloys, steels, and titanium alloys. Leaflet 406/1 section 5.2 defines special environments in which titanium is susceptible to SCC. Tables 1, 2, and 3 provide relative SCC susceptibilities for various aluminum and steel alloys.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 3.4.2 (v) recommends that the design of aircraft parts ensure a grain flow appropriate to the direction of stress to minimize stress corrosion cracking.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.1.1 with table, Par. 5.4.3.1.2 and 5.4.3.1.4, Par. 5.4.3.1.5 and Par. 5.4.3.1.6, and Table 1 of MIL-STD-1568 are identical in sequential order to Par. 3.3.3.1.1.1 and Table 3, Par. 3.3.3.1.2 and 3.3.3.1.4, Par. 3.3.3.1.5 and Par. 3.3.3.1.6, and Table 4 of ADS-13C listed above.
MIL-STD-889. Dissimilar Metals. (U.S.)	Stress corrosion cracking and hydrogen embrittlement are not addressed.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Chap. 13 addresses stress corrosion cracking theory and provides 17 case histories of SCC. Chap. 14 addresses corrosion fatigue theory and specifically addresses stress corrosion fatigue theory in Section 14.2. Chap. 12 addresses hydrogen embrittlement theory and provides 8 case histories of hydrogen embrittlement.

II. Corrosion Mechanisms

B. Exfoliation/Intergranular Corrosion

SD-24, Volume 1 (U.S. Navy), requires the selection of aluminum alloys and heat treatments which minimize susceptibility to pitting, exfoliation, and stress corrosion. A table of exfoliation resistance of aircraft alloys is given. MIL-S-5002 (U.S.) specifies the use of cleaning materials for corrosion and heat resisting steels that do not result in attack of the surface, either pitting or intergranular. Daily tests are required to assure that no attack occurs. ADS-13 (U.S. Army) requires cleaning of metallic surfaces in accordance with MIL-S-5002 (no damage, including freedom from pits, intergranular attack, and etching). DARCOM-R 702-24, Appendix A (U.S. Army) contains a discussion of the factors affecting intergranular corrosion and methods for reducing the possibility of intergranular attack. NAVMAT P4855-2 (U.S. Navy) has a short section explaining the mechanism of intergranular corrosion and the importance of proper selection of aluminum alloys.

AIR 7251/C (France) gives a definition of intercrystalline corrosion and exfoliation, a general method for combating this type of attack (isolation from the ambient environment), and the general cause of the phenomenon. The susceptibilities to intercrystalline attack of several French aluminum alloys also are given. DEF STAN 00-970, Volume 1 (U.K.), has a short chapter of general rules for avoiding exfoliation. However, much more specific and detailed information is contained in Leaflet 405/1 on precautions to be taken to avoid exfoliation corrosion. After explaining the causes of exfoliation corrosion, Leaflet 405/1 discusses the importance of heat treatment and alloy selection. A table of relative susceptibilities to exfoliation of various aluminum alloys is given. Although there is no specific reference to exfoliation in the main body of IATA DOC. GEN/2637A, the appendix gives examples of problems experienced in the past and some of the alloys susceptible to exfoliation. MIL-STD-1568A (U.S. Air Force) only mentions exfoliation corrosion briefly as a possible cause of service failures that must be considered in material selection. The AGARD Corrosion Handbook, Volume 1, has a chapter on intergranular and exfoliation corrosion. The causes, mechanisms, and prevention of exfoliation corrosion are discussed, and several case histories are presented.

DESIGN DOCUMENT (COUNTRY)	II. Corrosion Mechanisms B. Exfoliation/Intergranular Corrosion
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par 3.2.2.1.3 addresses aluminum alloys and exfoliation corrosion susceptibility. A list of exfoliation resistant alloys and tempers for aluminum is provided.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems. (U.S.)	Exfoliation/intergranular corrosion is not addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace WeaponsSystems. (U.S.)	Exfoliation/intergranular corrosion is not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Exfoliation/intergranular corrosion is not addressed.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Appendix A Section 1.8.6 addresses intergranular corrosion in aluminum, brasses, and stainless steels. A list of design precautions is provided to limit both intergranular and stress corrosion.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 4 addresses intergranular corrosion as a common corrosion problem. Although in most metals the grain structure is such that one grain may be anodic to another, in the case of aluminum alloys the grain boundaries are anodic to the grains which can cause corrosion of subsurface layers without being detected. The solution is an informed choice of alloys.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Section 3,21 entitled "aluminum alloys" addresses intergranular corrosion or "intercrystalline corrosion." The cause of this type of corrosion is related to the thermal history of the material and the solution is to isolate intergranular corrosion sensitive material from the ambient environment. A warning is provided that intergranular corrosion sensitive material is also stress corrosion sensitive.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Chapter 405 entitled "exfoliation corrosion of aluminum alloys" specifically provides instructions, restrictions, and precautions to safely design without exfoliation corrosion. Leaflet 405/1 provides greater detail than Chapter 405 and a table of susceptibility to exfoliation corrosion of various wrought aluminum alloys.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Exfoliation/intergranular corrosion is not addressed.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Exfoliation/intergranular corrosion is not addressed.
MIL-STD-889. Dissimilar Metals. (U.S.)	Exfoliation/intergranular corrosion is not addressed.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Chapter 10 provides a brief but detailed explanation of exfoliation/intergranular corrosion. The required heat treating procedures for susceptible metals are briefly described to minimize this form of corrosion. Eight case histories of exfoliation/intergranular corrosion induced failures provide a more complete view of this interesting and unique form of corrosion.

II. Corrosion Mechanisms

C. Galvanic Corrosion

SD-24, Volume 1 (U.S. Navy) states that the use of dissimilar metals in contact shall be limited to applications where similar metals cannot be used due to peculiar design requirements. When dissimilar metals are used they must be protected in accordance with MIL-STD-889, which is used by all three U.S. services. MIL-STD-889 gives requirements and methods for minimizing galvanic corrosion. It also contains a table that shows which metals are compatible and which are incompatible in sea water, marine atmosphere, and industrial atmosphere, respectively. MIL-S-5002 (U.S.) mentions the use of inorganic coatings for corrosion and stress corrosion resistant materials in contact with dissimilar metals, but has no other references to dissimilar metals. MIL-F-7179 (U.S.) gives requirements for sealing and painting dissimilar metals without stating that the purpose of the sealing and painting is to prevent galvanic corrosion. Appendix I to ADS-13 (U.S. Army) recommends that provisions be made to assure dissimilar metal couples not be used especially those with a potential difference greater than 0.10 volt. Weapons system contractors are required to assure recognition of the possibility of deterioration caused by the incompatibility of metals and materials, and to make a maximum effort to provide means of separation if material changes are not practicable. Several other provisions are listed to help prevent galvanic corrosion, such as sealing and painting. The U.S. Army also includes galvanic corrosion in its DARCOM-R 702-24 definition of deterioration which is to be considered in the Material Deterioration Prevention and Control (MADPAC) Program. Appendix A of DARCOM-R 702-24 contains a definition of galvanic corrosion and preventive measures to be taken. NAVMAT P4855-2 (U.S. Navy) discusses problems associated with the coupling of dissimilar metals in avionics equipment and the importance of adhering to the requirements of MIL-STD-889 and MIL-STD-454, Requirement 16. A table of the galvanic series in sea water is also presented. AIR-7251/C (France) specifically points out galvanic corrosion problems possible when either magnesium or titanium is one of the metals in a dissimilar couple. The risk of galvanic attack in heterogeneous assemblies is also discussed and a table of galvanic couple corrosion resistance is given. Leaflet 801/3 of DEF STAN 00-970, Volume 1 (U.K.), covers avoidance of galvanic corrosion at bimetallic contacts. Recommendations are made for both mild and severe environments and a table rates the degree of corrosion likely at various bimetallic contacts based on actual service experience. IATA DOC. GEN/2637A recommends avoidance of dissimilar metal contact and the use of a suitable protective treatment where contact cannot be avoided. MIL-STD-1568A (U.S. Air Force) refers to MIL-STD-889 to define dissimilar metals. Interdeposition of an insulating or corrosion inhibiting material between the joining surfaces, or interdeposition of a material that will reduce the electrochemical potential of the joint is recommended where dissimilar metal contact cannot be avoided. The AGARD Corrosion Handbook, Volume 1, has a chapter devoted to galvanic corrosion. Several case histories are given and general prevention methods are discussed.

DESIGN DOCUMENT (COUNTRY)	II. Corrosion Mechanisms C. Galvanic Corrosion
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.4.1.2.3 references MIL-STS-889 for galvanic corrosion and its prevention.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems. (U.S.)	Section 3.7.3 addresses coatings and plating systems for control of galvanic and other types of corrosion.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Galvanic corrosion is not specifically addressed but section 3.6 addresses specific requirements of coating and sealing for corrosion protection.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Table I addresses galvanic corrosion and galvanic compatibility in accordance with MIL-STD-889.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Appendix A section 1.5 encourages the use of galvanically compatible materials during design as defined in Tables X and XI of MIL-STD-186. Appendix A section 1.8.4 addresses galvanic corrosion and the treatment required to correct specific nonpermissible galvanic couples. Appendix A section 1.8.8 addresses "red plaque" corrosion or galvanic corrosion of electrical wiring.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Due to the nature of avionics design, galvanic corrosion is an inherent concern with avionics and is indirectly addressed throughout the specification. Table 2-2 is a galvanic series in sea water for metals and alloys. Section 5-2 addresses galvanic couples in material selection and use.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Appendix 2 provides a table entitled "Corrosion Resistance Level of Galvanic Couples."
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Leaflet 801/3 is entitled "Precautions Against Corrosion and Deterioration, Avoidance of Galvanic Corrosion at Bimetallic Contacts" and gives recommendations on the avoidance of corrosion due to galvanic action of dissimilar metals. Table I of Leaflet 803/1 provides a relative ranking of corrosion at various bimetallic contacts.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Galvanic corrosion is not specifically addressed. Dissimilar metal contact is cautioned against in Section 3.4.2 (ii).
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.2.4 addresses dissimilar metals and precautions necessary to minimize galvanic corrosion. MIL-STD-889 is referenced as a guide to minimizing galvanic corrosion.
MIL-STD-889. Dissimilar Metals. (U.S.)	This document is the major document specifically addressing galvanic corrosion. Section 3 defines dissimilar metals, galvanic corrosion, and the galvanic series. Section 5 addresses minimizing dissimilar metal corrosion, also precautions and methods for joining dissimilar metals. Table I provides a rating of corrosion intensity for various bimetallic contacts.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Chapter 8 provides an excellent explanation of galvanic corrosion and methods to minimize or prevent it. In addition, four case histories of galvanic corrosion failures are addressed.

III. Design Factors

A. Drainage Provisions

Drainage provisions are not addressed in three documents due to their specific and narrow areas of concern. MIL-S-5002C (U.S. Navy) which addresses surface treatments and inorganic coating for metal surfaces of weapons systems, MIL-F-7179F (U.S. Navy) which addresses finishes, coatings, and sealants for the protection of aerospace weapons systems, and MIL-STD-889 (U.S. Air Force) which addresses dissimilar metals make no reference to drainage provisions.

SD-24L Volume I (U.S. Navy) provides specific direction for the proper location and design of drain holes to allow maximum drainage of fluids which can accumulate and exacerbate corrosion within aircraft structures. Appendix I of ADS-13C (U.S. Army) provides similar direction for properly locating drain holes and further requires a minimum acceptable drain hole size.

DEF STAN 00-970 in Chapter 801 addresses drainage and specifically requires that no drainage system shall be designed which is made ineffective with one drain or drain-hole blocked. It further requires that particular attention be paid to areas of the aircraft where liquids are likely to be spilled, such as battery areas, galley, and toilets. Additionally, both DEF STAN 00-970 and IATA Document Gen/2637A, Issue 2 requires that any area which can not be properly drained shall be filled with inert, non-absorbent, caulking or filling material to prevent moisture intrusion and retention. The AGARD Corrosion Handbook, Volume I, provides examples of proper drain hole design in several figures which show both good and bad designs of lightening holes, water traps, and faying surfaces to minimize corrosion of aircraft structure which normally is susceptible to moisture/liquid entrapment.

DARCOM-R 702-24 (U.S. Army), Regulation 7251/C (France), and MIL-STD-1568 present only general requirements for drainage but do not provide specific design criteria. MIL-STD-1568 has a singular requirement to design with an aim of excluding rain and airborne spray while insuring sufficient ventilation to prevent moisture retention and buildup.

Many of the documents which address drainage require that the attitude of the aircraft on the ground or in flight be considered during the design process in order to maximize the use of drainage. The documents further stress that proper venting in addition to proper drain hole design is critical to insure effective drainage in corrosion control.

DESIGN DOCUMENT (COUNTRY)	III. Design Factors A. Drainage Provisions
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par.3.2.4.1.2.3 addresses drain holes and proper design and location to maximize drainage of accumulated fluids.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Drainage provisions are not addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Drainage provisions are not addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par.3.3.2 of Appendix I provides general design rules for corrosion prevention with respect to drainage.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Par. 1.5.2 of Appendix A addresses drainage.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 5.3 addresses drainage requirements under the subsection entitled "Moisture Intrusion." Table 5.2 provides a very extensive list of "Do's" of equipment design. One recommended "Do" is the use of low point drains. Table 5.3 provides a very extensive list of "Don'ts" of equipment design. Don't permit water trap areas is an example.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 1.4 addresses drainage provisions.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Sections 3.1 though 3.3 of Chapter 801 recommend methods for preventing the entry of water and other fluids. Section 3.4 of Chapter 801 addresses drainage provisions.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Par.3.4.2(ii) addresses drainage provisions which should be considered during the design process. Par.3.(viii) of Appendix 1 addresses past problems experienced due to improper drainage.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.2.1 addresses exclusion of rain and spray. Par. 5.4.2.3 addresses drainage provisions.
MIL-STD-889. Dissimilar Metals. (U.S.)	Drainage provizions are not addreses.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Section 6.3 entitled "Design Principles" addresses drainage provisions.

III. Design Factors

B. Assembly Practices

Assembly practices that will minimize the possibility of corrosion in service are addressed in all the design documents used by the NATO countries. SD-24 (U.S. Navy) requires sealing of all faying surfaces with edges leading to the exterior of the aircraft. Several other provisions are given for sealing and otherwise preventing the collection of moisture as well as other design features required for engine exhaust areas, missile blast areas, etc.
MIL-F-7179 (U.S.) has several pages of requirements for sealing and assembly of various types of parts (slip fits, press fits, coiled springs, fasteners, electrical parts, etc.) Appendix I of ADS-13 (U.S. Army) contains a section of suggestions on design and assembly to minimize corrosion. There is also a general requirement for "adequate precaution" to be taken during manufacturing to assure the integrity of corrosion prevention requirements. Appendix A of DARCOM-R-702-24 has a section on design considerations that includes some assembly practices for minimizing corrosion. Precautions that apply to specific materials or problems are interspersed throughout various sections. The list of "Dos and Don'ts" in NAVMAT P4855-2 (U.S. Navy) gives many suggestions for optimizing avionics equipment design and assembly with respect to corrosion resistance. Specific information on the protection of assemblies is presented in AIR 7251/C (France) including requirements for pretreatment, sealing, and painting. Welded and glued assemblies, dissimilar metal assemblies, sliding assemblies, and force fits of various metallic parts are included. Most of the recommended assembly practices for the U.K. are given in Chapter 801 of DEF STAN 00-970, Volume 1, although some are in individual leaflets. Chapter 801 is very thorough, covering all phases of sealing, assembling, and painting of most types of aircraft parts. Chapter 3 of IATA DOC. GEN/2637A contains both basic guidelines for assembly practices to minimize corrosion and acceptable means of compliance. Much general information is given as well as recommendations for protecting specific parts (cabin floors, galleys, avionic equipment, etc.). MIL-STD-1568A (U.S. Air Force) covers materials and processes without specifically mentioning assembly for the most part. However, there are a few paragraphs on the maintenance of corrosion integrity during manufacturing and removing debris after assembly. MIL-STD-889 (U.S.) covers recommended practices for avoiding galvanic corrosion of dissimilar metal assemblies. The AGARD Corrosion Handbook, Volume 1, contains general information on practices to be avoided during assembly and recommended practices.

DESIGN DOCUMENT (COUNTRY)	III. Design Factors B. Assembly Practices
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Corrosion preventive assembly practices are addressed in Par. 3.2.4.1.2.3.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Assembly pratices are not specifically addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Section 3.6 addresses corrosion preventive assembly practices.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Table 1 of Appendix I provides general techniques to follow during design and assembly to minimize corrosion. Par. 3.3.3.1.13 addresses corrosion prevention during manufacturing operations.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Assembly practices are not specifically addressed although "problematic areas" which are incorporated in the assembly process are addressed in Section 1.8 of Appendix A.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 5.3 addresses hermetic sealing, pressurization, and the use of sealants to prevent corrosion in the final assembly of avionics. Table 5.2 provides a list of "Do's" of equipment design which include several positive assembly practices. Table 5.3 provides a similar list of "Don'ts".
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Section 3.3 addresses assembly practices. Par. 3,3145 forbids direct assembly of wood and magnesium. Section 3,32 addresses rotating or sliding assemblies. Section 3,33 addresses force fits.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Section 3 of leaflet 400/2 addresses installation precautions in the use of magnesium. Leaflet 406/1 cautions the use of higher strength steels where assembly stresses are high. Par. 7.6 and 7.7 of Chapter 801 address painting in relation to assembly and exceptions to normal requirements. Chapter 801 Section 23 and 24 address additional assembly pratices.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 3.7 addresses assembly practices. Section 3 of Appendix 2 provides specific assembly practices for specific parts and areas of aircraft.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Section 5.5 addresses corrosion preventive assembly practices.
MIL-STD-889. Dissimilar Metals. (U.S.)	Par. 5.2 addresses acceptable assembly practice to avoid galvanic corrosion.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Section 6.3 provides guidelines for corrosion control during design. Section 6.4 provides guidelines for corrosion control during assembly.

III. Design Factors

C. Grain Flow

In order to minimize the danger of stress corrosion cracking in aluminum alloys, SD-24 (U.S. Navy) requires that sustained residual stresses in the longitudinal grain flow direction be not over 50 percent of the material specification minimum yield strength, not over 35 percent in the long transverse direction, and not over 15 percent in the short transverse direction. Materials with high resistance to SCC, such as 7075-T73 are not required to meet these requirements. Stresses may be as high as 75 percent in any grain direction for these materials. Additionally, SD-24 requires that optimum grain flow orientation be used to minimize fatigue failures. Internal grain flow in the direction of principal stresses is required in forgings.

Grain flow requirements for aluminum forgings are given in connection with shot peening requirements in both ADS-13 (U.S. Army) and MIL-STD-1568 (U.S. Air Force).

AIR 7251/C (France) requires that very special attention be paid to force fits that might set up tensile stresses in the short transverse direction of forged or drawn parts.

DEF STAN 00-970 mentions grain flow in connection with exfoliation of aluminum alloys and again in connection with SCC.

IATA DOC. GEN/2637A briefly discusses the importance of grain flow in minimizing SCC.

The AGARD Corrosion Handbook, Volume I, addresses the effect of grain flow in exfoliation corrosion and presents a table comparing failure times in 3.5% NaCl of various aluminum alloy specimens stressed in the three principal grain directions.

DESIGN DOCUMENT (COUNTRY)	III. Design Factors C. Grain Flow
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par.3.2.4.1.2.1 addresses maximum allowable stress in each grain flow direction in aluminum alloys.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Grain flow is not specifically addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Grain flow is not specifically addressed.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Grain flow concerns are addressed in Par. 3.3.3.1.1.4 of Appendix I under shot peening for stress corrosion resistance.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Grain flow is not specifically addressed.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Grain flow is not specifically addressed.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 3,331 addresses grain flow in connection with force fits.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Leaflet 405/1 Note 1 addresses grain structure and its influence on 2000 series aluminum alloy corrosion susceptibility. Section 3 of Leaflet 406/1 briefly discusses grain flow as does Note 7 of Table 1 of Leaflet 406/1.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 3.4.2(v) briefly addresses grain flow.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Grain flow is briefly addressed in Par. 5.4.3.1.4 which addresses shot peening for stress corrosion resistance.
MIL-STD-889. Dissimilar Metals. (U.S.)	Grain flow is not addressed.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Chapter 10 addresses the effect of grain flow in exfoliation corrosion. Chapter 13, Table 13-1 presents the highest tension stresses at which aluminum alloy test specimens of different orientations to the grain structure would not fail in SCC in 3.5% NaCL alternate immersion. Several of the Case Histories in Chap. 13 illustrate the importance of grain flow direction in SCC.

IV. Finishing Requirements

A. Aluminum Alloys

SD-24L (U.S. Navy) references MIL-F-7179 for finishing requirements and MIL-S-5002 for inorganic coating requirements. MIL-F-7179 is used by all three U.S. services for aircraft finishing. It contains requirements for types of paints to be used in each application as well as minimum thicknesses to be applied. Requirements for the use of sealants and preservatives are also given. Contractors are required to submit a finish specification complete with proposed deviations and reasons for deviations.

MIL-S-5002 gives requirements and limitations (such as maximum allowable service temperature) for metallic coatings and metallic-ceramic coatings. With respect to aluminum alloys, the specification prohibits the use of uninhibited alkaline cleaning solutions, and abrasive cleaning with steel wool and wire, or copper based wire brushes. All aluminum alloy aircraft parts must be anodized or given a chemical conversion coating treatment.

ADS-13 (U.S. Army) refers to MIL-S-5002 for specific requirements, but contains detailed requirements for anodizing and surface treating 2000 and 7000 series aluminum alloys. For organic finishing ADS-13 refers to MIL-F-7179. Organic finishing requirements in ADS-13 are general, not specific to aluminum alloys.

Appendix A of DARCOM-R-702-24 (U.S. Army) calls for finishing in accordance with MIL-STD-171 or MIL-STD-186. It does not present specific requirements for aluminum alloys. NAVMAT P4855-2 (U.S. Navy) discusses the electrical resistance of chemical conversion coatings for aluminum alloys along with general information on protective treatments for aluminum. AIR 7251/C (France) contains requirements for inorganic treatment of aluminum alloys (anodizing or chemical oxidation) plus organic coating. The sections on the treatment of various types of assemblies present specific finishing requirements for "light alloy" (aluminum) parts. Chapter 801 of DEF STAN 00-970, Volume 1 (U.K.), gives general requirements for painting aircraft surfaces without referring to aluminum alloys specifically. Detailed information on inorganic coatings for aluminum alloys are given in the metal treatment section. Appendix 2 of IATA DOC. GEN/2637A gives basic requirements for the protection of both cast and wrought aluminum alloys. MIL-STD-1568A (U.S. Air Force) requires all non-clad 2000 and 7000 series aluminum alloy parts to be anodized. Clad 2000 and 7000 series may be either anodized or chemical film treated. Organic coating requirements are general for exterior, interior, etc., and are not specific with respect to aluminum alloys. MIL-STD-889B (U.S.) recommends various coating systems for aluminum in contact with dissimilar metals. The AGARD Corrosion Handbook, Volume 1, has a table of protection schemes for aluminum alloys and descriptions of chemical conversion coating and anodizing.

DESIGN DOCUMENT (COUNTRY)	IV. Finishing Requirements A. Aluminum Alloys
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.6 addresses finishing requirements which are referenced to Mil-7179.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Par. 3.4.2.1 addresses cleaning requirements for aluminum and aluminum alloys. Section 3.5 addresses surface treatments of aluminum and aluminum alloys. Section 3.7 addresses metallic coatings, metallic-ceramic and ceramic coatings, coatings for corrosion control, and coatings for functional purposes. Section 3.8.2 addresses hard anodic coatings for aluminum and its alloys.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Table II provides a definition of minimum dry film thickness requirements for aluminum and aluminum alloys in exterior and interior applications. Aluminum and aluminum alloys are not specifically addressed as a subject area but are instead addressed within appropriate individual part finishing requirements.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.3.2 addresses the inorganic finishing requirements for aluminum and aluminum alloys. Section 3.3.3.4 addresses organic finishing requirements for all surfaces.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Section 1.7 of Appendix A addresses finishes and surface treatments on all substrates.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 5.2 addresses aluminum and aluminum alloy finishing requirements under the subsection titled "Surface Treatments". The subsection titled "Organic Coatings" specifies any additional coating which may be required.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 3,214 addresses normal protection for aluminum alloys. Par. 4,21 specifies the standard paint for woods and metals. Section 4,32 addresses anodic oxidation and chemical oxidation of aluminum alloys. Par. 5,21 addresses surface preparation of aluminum.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Section 10 of Chap. 801 addresses finishing requirements for aluminum alloys. Par. 10.1 addresses general requirements. Par. 10.1.2 addresses selection of surface treatment methods. Par. 10.2 addresses exceptions and special cases to the general requirements. Par. 10.3 addresses the temperature limitations in processing aluminum alloys.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 1.2 of Appendix 2 addresses finishing requirements for aluminum alloys.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.6.1.1 addresses inorganic finishing requirements for aluminum alloys. Section 5.7 addresses organic finishing requirements for aluminum alloys and other substrates.
MIL-STD-889. Dissimilar Metals. (U.S.)	Par. 30.4 of Appendix A provides a list of recommended treatments for aluminum and aluminum alloys in order of protective effectiveness.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Par. 6.5.2. addresses surface conversion coatings for aluminum and other metals. Anodizing and chromate filming are specifically addressed. Table 6-1 provides typical protection schemes for aluminum, magnesium and non-corrosion resistant steels. The schemes include cleaning steps, pre-treatment steps, surface sealing, paint primer, paint finish, and any further protection.

IV. Finishing Requirements

B. Steels

SD-24L (U.S. Navy) references MIL-F-7179 for finishing requirements and MIL-S-5002 for inorganic coating requirements. MIL-F-7179 is used by all three U.S. services for aircraft finishing. It contains requirements for types of paints to be used in each application as well as minimum thicknesses to be applied for exterior and interior applications. Requirements for the use of sealants and preservatives are also given. Contractors are required to submit a finish specification complete with proposed deviations and reasons for deviations.

MIL-S-5002 gives requirements and limitations (such as maximum allowable service temperature) for metallic coatings and metallic-ceramic coatings. The list of other coatings addressed includes plating systems, zirconium oxide coating, thermal sprayed coatings, and phosphate treatments.

ADS-13 (U.S. Army) refers to MIL-S-5002 for specific inorganic finishing requirements, but contains detailed requirements for cadmium plating and aluminum coatings. ADS-13 refers to MIL-F-7179 for organic finishing requirements. In general these requirements are for all substrates and not specifically steels.

Appendix A of DARCOM-R-702-24 (U.S. Army) calls for finishing in accordance with MIL-STD-171 or MIL-STD-186. The requirements are general for all substrates rather than specifically for steels. NAVMAT P4855-2 (U.S. Navy) addresses finishing systems for steels under the surface treatments and the plating systems subsections. The requirements are general for all substrates rather than specifically for steel.

AIR 7251/C (France) contains requirements for inorganic treatment of steels followed by organic coating. The combination of both requirements is called normal protection by AIR 7251/C.

Chapter 801 of DEF STAN 00-970, Volume I (U.K.), gives general requirements for the treatment of metal parts, followed in a subsequent section by specific treatment requirements for steels. Chapter 801 is unique in that specific finishing requirements are addressed for steel spare parts. All protective materials and processes specified in Chapter 801 are listed in one table for easy reference. Appendix 2 of IATA DOC. GEN/2637A gives basic requirements for the protection of steels.

MIL-STD-1568A (U.S. Air Force) specifically addresses cadmium and aluminum coating for steels but addresses organic finishing requirements for all substrates including steels. MIL-STD-889 (U.S.) recommends various treatments for steels in order of protective effectiveness. The AGARD Corrosion Handbook, Volume 1, addresses several inorganic coatings for steels including phosphate, cadmium, chromium, nickel, electroless nickel, aluminum, and zinc. Paint systems are addressed for use over steel or other substrates. A table is provided for typical protection schemes for steels which start with cleaning and pretreatment steps and finish with paint system requirements.

DESIGN DOCUMENT (COUNTRY)	IV. Finishing Requir B. eels
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Section 3.2.6 addresses finishing requirements for all substrates.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Section 3.7 addresses coatings for steels and other substrates. The list includes plating systems, aluminum coating, metallic-ceramic, zirconium oxide coating, thermal sprayed coatings, and phosphate treatments.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Table II provides a definition of minimum dry film thickness requirements for steels in exterior and interior applications. Steels are not specifically addressed as a subject but are instead addressed within specific part finishing requirements.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par. 3.3.3.3.3 addresses cadmium coatings for steel parts. Par. 3.3.3.3.4 addresses aluminum coatings for steel parts. Section 3.3.3.4 addresses organic finishing requirements for all surfaces.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Section 1.7 of Appendix A addresses finishes and surface treatments on all substrates.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 5.2 addresses finishing systems for steels under the "Organic Coating" subsection and the "Plating Systems" subsection.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 3,232 addresses normal protection for steels. Par.4,21 specifies the standard paint for wood and metals. Section 4,31 addresses phosphating, metal sprayed coatings, and zinc and cadmium electrolytic deposits on steels.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Section 7 of Chapter 801 addresses the treatment of metal parts in general. Section 8 of Chapter 801 addresses the treatment of steels. Par. 25.2 of Chapter 801 addresses the finishing requirements of steel spare parts. Table 1 is a "List of Protective Materials & Processes Called Up in Chap. 801."
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 1.5 of Appendix 2 addresses finishing requirements for steels.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.6.1.2 addresses cadmium coatings for all steel parts. Par. 5.6.1.3 addresses aluminum coatings for steel parts. Section 5.7 addresses organic finishing requirements for steels and other substrates.
MIL-STD-889. Dissimilar Metals. (U.S.)	Par. 30.4 of Appendix 2 provides a list of recommended treatments for steels in order of protective effectiveness.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Par. 6.5.2 addresses phosphate coatings for steels. Par. 6.5.3 addresses metallic coatings for steels which include cadmium, chromium, nickel, electroless nickel, aluminim, and zinc. Par. 6.6.2 addresses paint systems for use over steel or other substrates. Table 6.1 provides typical protection schemes for non-corrosion resistant steels.

IV. Finishing Requirements

C. Corrosion Resistant Steels

Specification SD-24 (U.S. Navy) requires finishing in accordance with MIL-F-7179. No specific requirements are given in SD-24 for finishing stainless steels. MIL-S-5002 gives requirements for cleaning corrosion and heat resisting steels, and passivation of these steels. The final operation for most corrosion resistant steels is passivation. Requirements for painting corrosion resistant steels are given in Table II of MIL-F-7179. Corrosion and heat resistant alloy plumbing lines are not required to be painted. ADS-13C (U.S. Army) refers to MIL-F-7179 for general organic finishing and coating requirements and MIL-S-5002 for inorganic coatings and surface finishing. The only requirement in ADS-13C specifically for corrosion resistant steels is for stainless steel fasteners in contact with aluminum alloys. They must be coated with cadmium or aluminum. Finishing requirements in DARCOM-R-702-24 (U.S. Army) are also general. DARCOM-R-702-24 refers to Military Standards
MIL-STD-186 or MIL-STD-171 for detailed requirements. Surface treatments, organic coatings, conformal coatings, and plating systems for avionics systems are discussed in NAVMAT P4855-2 (U.S. Navy). AIR 7251/C (France) gives finishing requirements for stainless steels. Passivation is the recommended treatment. Martensitic stainless steels may then be electropolished or receive a protective coating. Chapter 801 of DEF STAN 00-970, Volume 1 (U.K.), gives general finishing requirements for corrosion resisting steels, and special requirements for parts in contact with aluminum alloy or magnesium alloy. Finishing requirements are also discussed in Leaflet 801/6. IATA Document GEN/2637A, Issue 2, Appendix 2, contains requirements for finishing corrosion resistant steels (generally chemical treatment or cadmium plating plus paint when in contact with aluminum). MIL-STD-1568 (U.S. Air Force) requires passivation of all corrosion resistant steels plus coatings for 400 series martensitic steels. Stainless steel fasteners in contact with aluminum must be cadmium or aluminum coated. General organic finishing requirements are also given without regard for the type of metal being coated. MIL-STD-889 (U.S.) tells how corrosion resistant steels should be finished when they are to be in contact with dissimilar metals. The AGARD Corrosion Handbook, Volume 1, contains a short discussion of passivation treatments for stainless steels.

DESIGN DOCUMENT (COUNTRY)	IV. Finishing Requirements C. Corrosion Resistant Steels
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Section 3.2.6 addresses finishing requirements.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Par. 3.4.2.4 addresses cleaning requirements for corrosion resisting steels. Section 3.7 addresses coatings for corrosion resisting steels. Par. 3.8.3 addresses surface treatments for corrosion resisting steels.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Table II provides a definition of minimum dry film thickness requirements for corrosion resistant steels in exterior and interior applications. Corrosion resistant steels are not specifically addressed as a subject but are instead addressed within specific part finishing requirements.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Section 3.3.3.4 addresses organic finishing requirements for all substrates.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Section 1.7 of Appendix A addresses finishes and surface treatments on all substates.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 5.2 addresses finishing systems for corrosion resistant steels under the "Organic Coatings" subsection and the "Plating Systems" subsection.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par.3,232 addresses normal protection for corrosion resistant steels. Par.4,21 specifies the standard paint for wood and metals.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Chapter 801 Section 9 addresses finishing requirements for corrosion resisting steels. Leaflet 801/6 addresses finishing requirements in Section 6.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 1.3 of Appendix 2 addresses finishing requirements for corrosion resistant steels.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Section 5.1.2 addresses the requirement for a finish specification. Section 5.4.3.3 addresses finishing requirements for stainless steel.
MIL-STD-889. Dissimilar Metals. (U.S.)	Sections 30.7 and 30.9 of Appendix A address finishing requirements for corrosion resistant steels.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Section 6.5.2 addresses finishing requirements for corrosion resistant steels.

IV. Finishing Requirements

D. Titanium

Specification SD-24L (U.S. Navy) requires finishing in accordance with MIL-F-7179. No specific requirements are provided in SD-24L for finishing titanium. MIL-S-5002 provides cleaning requirements and requirements for removal of inorganic contamination on titanium. Specific coating of titanium is not addressed although restrictions on the use of cadmium plate on or in contact with titanium are provided. Finishing requirements are addressed in MIL-F-7179 to protect titanium faying surfaces. Table II of MIL-F-7179 gives the painting requirements for titanium and titanium alloys in exterior and interior applications to blend with adjacent painted areas. MIL-F-7179 does not require titanium or titanium alloys to be painted for other than cosmetic reasons.

ADS-13C (U.S. Army) provides general finishing requirements applicable to all substrates. ADS-13C refers to MIL-F-7179 for general organic finishing and coating requirements and MIL-S-5002 for inorganic coatings and surface finishing. Finishing requirements in DARCOM-R-702-24 (U.S. Army) are also general. DARCOM-R-702-24 refers to Military Standards MIL-STD-186 or MIL-STD-171 for detailed requirements. Surface treatments, organic coatings, conformal coatings, and plating systems for avionics systems are discussed in NAVMAT P4855-2 (U.S. Navy) but no requirement is specifically made for the coating of titanium. Regulation AIR 7251/C (France) addresses titanium finishing requirements in general and then addresses titanium finishing requirements for specific applications in a subsequent section. Chapter 801 of DEF STAN 00-970, Volume I (U.K.), gives general finishing requirements for titanium parts followed by specific requirements for titanium parts in contact with magnesium alloys, aluminum alloys, non-corrosion resisting steel, and non-metallic materials. IATA Document Gen/2637A, Issue 2, Appendix 2, provides no requirements for finishing titanium. MIL-STD-1568 provides special precautions to follow with respect to cadmium plating and silver brazing in order to avoid the possibility of hydrogen embrittlement. In addition, MIL-STD-1568 provides a list of chemicals to avoid in order to avoid stress corrosion cracking in titanium alloys. MIL-STD 889 (U.S.) gives finishing requirements for titanium in contact with dissimilar metals. Cadmium and zinc are prohibited by MIL-STD-889 to contact titanium while silver is permitted as a coating over titanium if it is applied over a layer of nickel. The AGARD Corrosion Handbook, Volume 1, cautions against using titanium in contact with phosphate ester fluids and cadmium plating. In addition, the AGARD Corrosion Handbook has a short discussion of anodic coatings for titanium and titanium alloys.

DESIGN DOCUMENT (COUNTRY)	IV. Finishing Requirements D. Titanium
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Section 3.2.6 addresses finishing requirements for all substrates.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems. (U.S.)	Par. 3.4.1.1 addresses cleaning requirements for titanium. Par. 3.4.2.6 addresses inorganic contamination removal on titanium. Section 3.7 addresses inorganic coatings. Par. 3.7.5 Footnote 3 addresses the restriction of cadmium on or in contact with titanium.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Section 3.6.2 and 3.6.3 address finishing requirements to protect faying surfaces. Table II provides the coating requirements for titanium and titanium alloys in exterior and interior applications to blend with adjacent areas.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Section 3.3.3.4 addresses organic finishing requirements for all substrates.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Section 1.7 of Appendix A addresses finishes and surface treatments on all substrates.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Finishing requirements for titanium and titanium alloys are not addressed.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Section 3,24 addresses titanium finishing requirements. Par. 3,314, 3,32, and 3,334 address titanium finishing requirements for specific applications.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Section 13 of Chapter 801 addresses finishing requirements for titanium and titanium alloys.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Finishing requirements for titanium are not addressed.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.4.3.4.3 provides "special precautions" to follow in finishing titanium to avoid the possibility of hydrogen embrittlement. Par. 5.5.1.1 provides a list of materials to avoid using in contact with titanium to prevent stress corrosion cracking.
MIL-STD-889. Dissimilar Metals. (U.S.)	Par. 30.10 of Appendix A addresses finishing requirements for titanium.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Par. 6.2 addresses caution in avoiding titanium contact with phosphate ester fluids and cadmium. Par. 6.5.2 addresses anodic coatings for titanium and titanium alloys.

IV. Finishing Requirements

E. Magnesium

Specification SD-24L (U.S. Navy) requires finishing in accordance with MIL-F-7279. No specific requirements are given in SD-24 for finishing magnesium. MIL-S-5002 provides cleaning requirements for magnesium followed by surface treatments which are applicable for magnesium alloys. Finishing requirements are addressed in MIL-F-7179 to protect magnesium faying surfaces. Table II of MIL-F-7179 gives the painting requirements for magnesium alloys in exterior and interior applications. ADS-13C (U.S. Army) refers to MIL-M-45202 or MIL-M-46080 for treatment prior to finishing with organic finishes in accordance with MIL-F-7179. Finishing requirements in DARCOM-R-702-24 (U.S. Army) are general. DARCOM-R-702-24 refers to MIL-STD-186 and MIL-STD-171 for detailed requirements. Organic and inorganic finishes for magnesium avionics components are discussed in NAVMAT P4855-2 (U.S. Navy). Regulation AIR 7251/C (France) addresses the finishing requirements for magnesium alloys which combines anodic and organic coating to provide what is referred to in regulation AIR-7251/C as "normal protection." DEF STAN 00-970 is unique in designating finishing requirements for magnesium alloys with additional requirements given for spare parts made of magnesium alloy. IATA Document Gen/2637A, Issue 2, provides no finishing requirements for magnesium alloys because it forbids their use on structural applications or in corrosion prone areas. MIL-STD-1568 (U.S. Air Force) refers to MIL-M-45202 or MIL-M-46080 for anodic treatment prior to finishing with organic finishes in accordance with MIL-F-7179. MIL-STD-1568 provides additional organic finishing requirements beyond MIL-F-7179 in that specific organic coatings allowable under MIL-F-7179 are singled out for various internal and external aircraft applications.
MIL-STD-889 (U.S.), Appendix A, provides several alternative treatments for magnesium dependent on the service environment. The AGARD Corrosion Handbook, Volume 1, addresses magnesium alloy finishing requirements and provides a table with a typical magnesium alloy protection scheme.

DESIGN DOCUMENT (COUNTRY)	IV. Finishing Requirements E. Magnesium
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Section 3.2.6 addresses finishing requirements for all substrates.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Par. 3.4.2.5 addresses cleaning requirements for magnesium. Section 3.6 addresses surface treatments of magnesium alloys.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Table II provides a definition of minimum dry film thickness requirements for magnesium alloys in exterior and interior applications. Par. 3.6.3.a addresses the use of sealant on magnesium when it is one of two dissimilar metal faying surfaces.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Par.3.3.3.3.5 addresses finishing requirements for magnesium alloys. Section 3.3.3.4 addresses organic finishing requirements for all substrates.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Section 1.7 of Appendix A addresses finishes and surface treatments on all substrates. Par. 1.8.3.7 addresses painting requirements on all substrates.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 4.2 addresses finishing requirements for magnesium alloys.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par.3,222 addresses the normal protection or finishing requirements for magnesium alloys.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Section 11 of Chapter 801 addresses the finishing requirements for magnesium alloys. Par. 25.4 of Chapter 801 addresses the finishing requirements for spare parts constructed of magnesium alloy.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	No specific finishing requirements are provided for magnesium alloys because they shall not be used on structural applications or in corrosion prone areas.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.6.1.4 addresses inorganic finishing requirements for magnesium alloys. Par. 5.7.1.3 addresses organic finishing requirements for magnesium alloys.
MIL-STD-889. Dissimilar Metals. (U.S.)	Par. 30.1 of Appendix 2 addresses the finishing requirements for magnesium alloys.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Par. 6.5.2 addresses finishing requirements for magnesium alloys. Table 6-1 provides a typical protection scheme for magnesium alloys.

IV. Finishing Requirements

F. Other Metals and Materials (Radomes, Etc.)

SD-24L (U.S. Navy) refers to Military Specification MIL-F-7179 for finishing and protective coating requirements. The only other requirements are that exterior surfaces be aerodynamically smooth and that organic coatings (other than fire insulating paints) not be employed for temperature control in inaccessible areas. MIL-S-5002C gives requirements for inorganic coatings on copper base parts. MIL-F-7179F includes finishing requirements for wood, plastics, ceramics, and rubber. A table of minimum dry film thicknesses of organic coatings for all substrates is also included. The table covers interior and exterior applications and primer and topcoat requirements. Appendix I of ADS-13 (U.S. Army) gives requirements for finishing beryllium, depleted uranium, and insulating blankets. General requirements for inorganic and organic finishes on all substrates are also given. Appendix A of DARCOM R 702-24 (U.S. Army) also covers general finishing requirements for all substrates. NAVMAT P4855-2 (U.S. Navy) discusses organic coatings, conformal coatings, and plating systems for most substrates in avionics equipment. Specific warnings are given against the use of silver or gold coatings directly on copper parts. AIR-7251/C (France) presents general finishing requirements for all substrates plus some specific requirements for "special protection products" and fabrics. General requirements for surface treatment and standard paint schemes for all aeroplanes are given in Chapter 801 of DEF STAN 00-970, Volume 1 (U.K.). There are also special sections on the treatment of copper alloys, wood, and synthetic resin composites. The International Air Transport Association's DOC. GEN/2637A, Appendix 2, makes recommendations for finishing non-metal fiber laminates, tungsten alloys, and depleted uranium in addition to giving general requirements for most aircraft parts. MIL-STD-1568A (U.S. Air Force) refers to MIL-F-7179 for organic finishes in general, but also gives specific requirements for rain erosion coatings for plastic parts, and finishing requirements for beryllium, depleted uranium, and insulating blankets. MIL-STD 889 presents finishing requirements for most metals and plated coatings used on aircraft when they are in contact with dissimilar metals. The AGARD Corrosion Handbook discusses general protective treatments, general paint schemes, sealants, inhibitors and water displacing compounds. The information given applies principally to the protection of steels, aluminum alloys and titanium alloys.

DESIGN DOCUMENT (COUNTRY)	IV. Finishing Requirements F. Other Metals and Materials
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Section 3.2.6 addresses finishing requirements for all substrates.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	Section 3.7.3 addresses finishing requirements for copper base alloys.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	Par. 3.6.21 addresses the finishing requirements for wood. Par. 3.6.22 addresses the finishing requirements for molded plastic & ceramics. Par. 3.6.24 addresses the finishing requirements for reinforced plastic parts. Par. 3.6.27 addresses the finishing requirements for rubber. Table II lists the minimum dry film thickness required for exterior/interior applications of paints.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Section 3.3.3.3 addresses inorganic finishes on all substrates. Section 3.3.3.4 addresses organic finishes on all substrates.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	Section 1.7 of Appendix A addresses finishes and surface treatments on all substrates.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	Section 5.2 addresses finishing requirements for most substrates under the "Organic Coatings", "Conformal Coatings", and "Plating Systems" subsections.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Section 4,2 addresses finishing requirements on all substrates. Par. 4,21 specifies the standard coating system for all substrates. Par. 4,22 specifies exceptions to the standard coating requirements. Par. 4.23 specifies the standard fabric coatings required.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	Section 7 of Chapter 801 addresses the general treatment of metal parts. Section 12 of Chapter 801 addresses the finishing requirements for copper and copper base alloys. Section 14 of Chapter 801 addresses the treatment requirements for metal tanks including integral tanks. Section 15 and 20 of Chapter 801 address the treatment requirements for wood, composites,and resins.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 1.6 of Appendix 2 addresses finishing requirements for non-metallic fibre resins. Section 1.7 of Appendix 2 addresses finishing requirements for tungsten alloys. Section 1.8 of Appendix 2 addresses finishing requirements for depleted uranium. Section 2. of Appendix 2 addresses general assembly finishes. Section 3. of Appendix 2 addresses specific parts/area/assembly finishing requirements.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Section 5.6 addresses the inorganic finishing requirements for all metal substrates. Section 5.7 addresses the organic finishing requirements for all substrates.
MIL-STD-889. Dissimilar Metals. (U.S.)	Section 30 of Appendix A addresses finishing requirements for zinc and zinc alloys, cadmium and beryllium, lead, tin, solders, indium, chromium plate, molybdenum, tungsten, silver, rhodium, palladium, gold, platium, their alloys, and graphite materials.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	Section 6.5 addresses the general protective treatments and surface coatings used by all countries. Section 6.6 addresses the general supplementary protection systems such as paint systems, jointing compounds and sealants, inhibitors, and water displacing compounds used by all countries.

V. Corrosion Prevention

A. Corrosion Control Plan

A Corrosion Control Plan is required by many of the specifications and standards dealing with corrosion prevention. However, emphasis on a plan varies from one document to the next. SD-24L (U.S. Navy) has a requirement for preparation of a corrosion prevention and control plan, but offers very little guidance on what it should contain. MIL-S-5002C covers only inorganic coatings and surface treatments, so it has no requirement for a corrosion control plan. MIL-F-7179F requires a contractor's finish specification, which is closely related to a corrosion control plan, but no corrosion control plan is required. The U.S. Army presents a very strong requirement for a corrosion control plan in ADS-13C and DARCOM-R 702-24. The plan is part of the Material Deterioration Prevention and Control (MADPAC) Program which is clearly defined in DARCOM-R 702-24. The U.S. Navy's NAVMAT P4855-2 is a design guideline for corrosion prevention in avionics equipment. It does not mention a corrosion control plan. The French corrosion protection document, AIR 7251C, requires a corrosion control plan called a "Protection Plan." Appendix 1 to AIR 7251C presents a model of the required plan. The United Kingdom does not require a corrosion control plan. No mention of a plan is made in any of the leaflets and chapters that make up DEF STAN 00-970, Volume 1. DOC. GEN/2637A of the International Air Transport Association contains many of the elements of a corrosion control plan itself, but does not require contractors to submit a written corrosion control plan. It does mention the operator's corrosion control program, however. In MIL-STD-1568A, the U.S. Air Force requires that the contractor prepare a written Corrosion Prevention and Control Plan. Requirements for the formation of an Air Force Advisory Board (AFAB) and a Contractor's Corrosion Team (CCT) are also given. MIL-STD-889B pertains to dissimilar metals only and makes no mention of a corrosion control plan. The AGARD Corrosion Handbook, Volume 1, also does not discuss requirements for a corrosion control plan.

DESIGN DOCUMENT (COUNTRY)	V. Corrosion Prevention A. Corrosion Control Plan
SD-24L. Volume 1. General Specification for Design and Construction of Aircraft Weapon Systems. Fixed Wing Aircraft. (U.S.)	Par. 3.2.4.1.2.3 addresses and defines the requirements of the corrosion prevention and control plan.
MIL-S-5002C. Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems. (U.S.)	A corrosion control plan is not addressed.
MIL-F-7179F. Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems. (U.S.)	A corrosion control plan is not specifically addressed but a requirement is provided in Par. 3.1.2 for a contractor's finish specification.
Aeronautical Design Standard ADS-13C Air Vehicle Material and Processes. (U.S.)	Appendix I addresses the requirement for providing a material deterioration, prevention and control (MADPAC) plan.
Department of the Army Regulation DARCOM-R 702-24. Material Deterioration Prevention and Control. (U.S.)	The entire document addresses the development of a material deterioration, prevention and control plan for the Army. Appendix B addresses tge requirements of what is necessary to comply with the specification.
NAVMAT P4855-2. Design Guidelines for Prevention and Control of Avionic Corrosion. (U.S.)	A corrosion control plan is not addressed.
Regulation AIR 7251/C. Instruction Sur La Protection Contre La Corrosion Des Aerodynes Et Autres Materials Aeronautiques. (France)	Par. 1,3 addresses the requirement for a corrosion control plan. Appendix 1 is a model of a protection plan as required by Par. 1,3.
DEF STAN 00-970. Design and Airworthiness Requirements for Service Aircraft. Issue 1. (U.K.)	A corrosion control plan is not addressed.
IATA Document GEN/2637A. Issue 2. Guidance Material on Design and Maintenance Against Corrosion of Aircraft Structures.	Section 3.2 briefly addresses a corrosion control program. Appendix 2 addresses the acceptable means of compliance with corrosion protection requirements for new aircraft structures as stated in Section 3.2.
MIL-STD-1568. Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems. (U.S.)	Par. 5.1.1 addresses the corrosion prevention and control plan. Section 2 addresses the schedule for submission of the corrosion prevention and control plan.
MIL-STD-889. Dissimilar Metals. (U.S.)	A corrosion control plan is not addressed.
AGARD Corrosion Handbook Volume 1. Aircraft Corrosion: Causes and Case Histories.	A corrosion control plan is not a topic which is specifically addressed.

Requests for documents can be directed to the following addresses by country of origin:

French:

Direction du Cedocar
26 Boulevard Victor
75996 Paris Armees

United Kingdom:

U.K. Ministry of Defence
Directorate of Standardization
Kentigern House
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United States:

Department of the Navy
Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, Pa. 19120-5099

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14. Abstract

This is the second Part of a Handbook of Aircraft Corrosion produced by the Structures and Materials Panel. This volume catalogues sources of information and requirements for corrosion control obtained from documents issued by NATO, France, UK and US authorities. IATA (International Air Transport Association) documents are also cited as a commercial reference.

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